Metacarpophalangeal Joint Replacement

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Outline

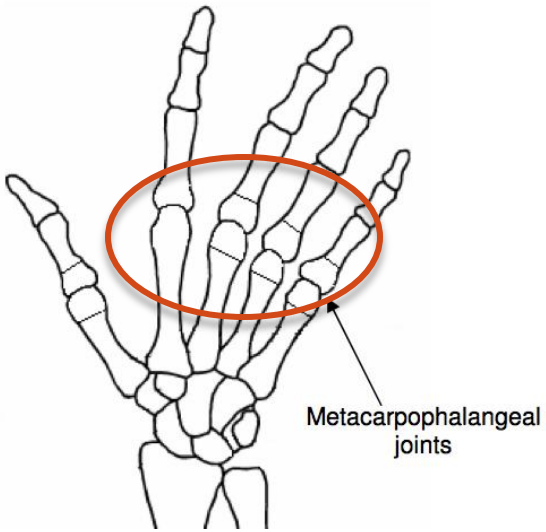
- Problem Statement
- Background
  - Competition
- Client Requirements
- Material Considerations
- Joint Designs
- Future Work

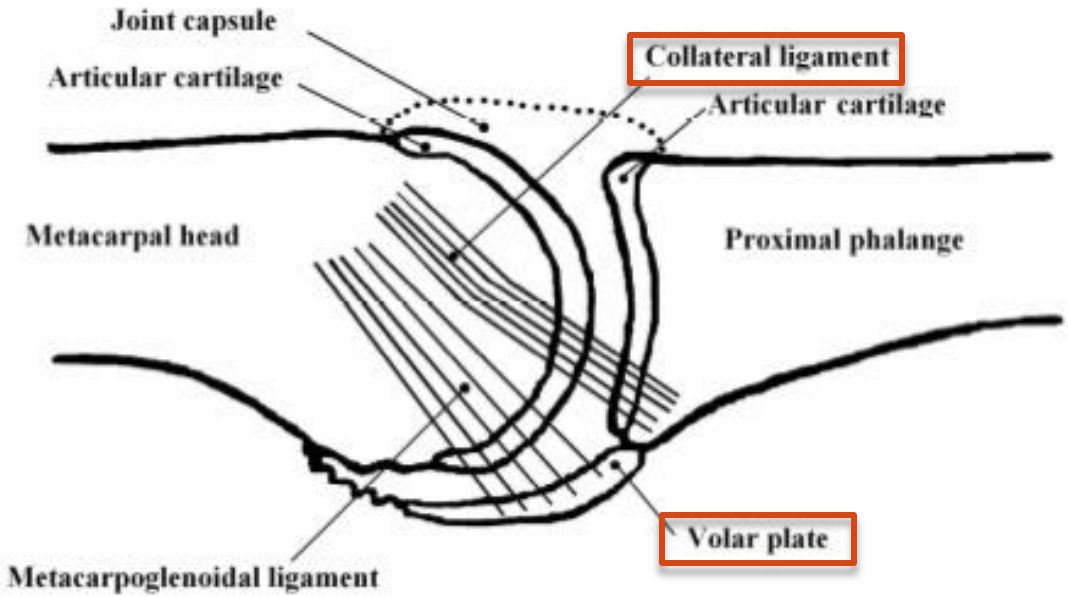
Problem Statement

The goal of this project is to design a **prosthetic replacement** for the **metacarpophalangeal (MCP) joint** that can be used in patients who do not have **collateral ligaments or a volar plate**. The prosthetic should have a **long lifespan** after implantation, allow the patient to maintain appropriate **range of motion,** have sufficient **strength and rigidity** between halves of implant, and **osteointegrate** to prevent micromotion.

Background

- Metacarpophalangeal joint



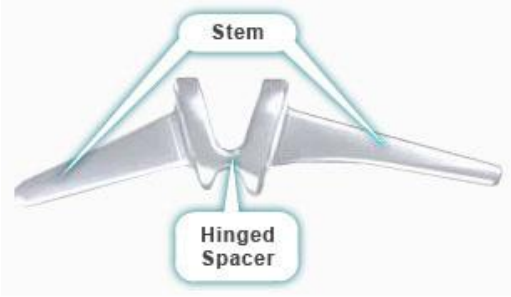


- Congenital defects, severe trauma

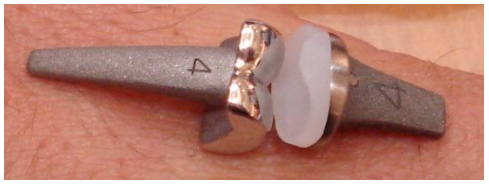
UW BME Design

Competition

- Silicone implants
  - Cause erosion in bone at implant-bone interface



- Semi-constrained finger prosthesis
  - Requires collateral ligaments to prevent tensile dislocation



UW BME Design

Client Requirements

- Must provide stability
- Must promote osteointegration
- Must have an appropriate range of motion
  - Flexion: 0-90°
  - Abduction/adduction: ~0-20°
- Must be biocompatible
- Must have a lifespan of 10-30 years
- Must not fail at implant/bone interface

Material for Articulating Surface

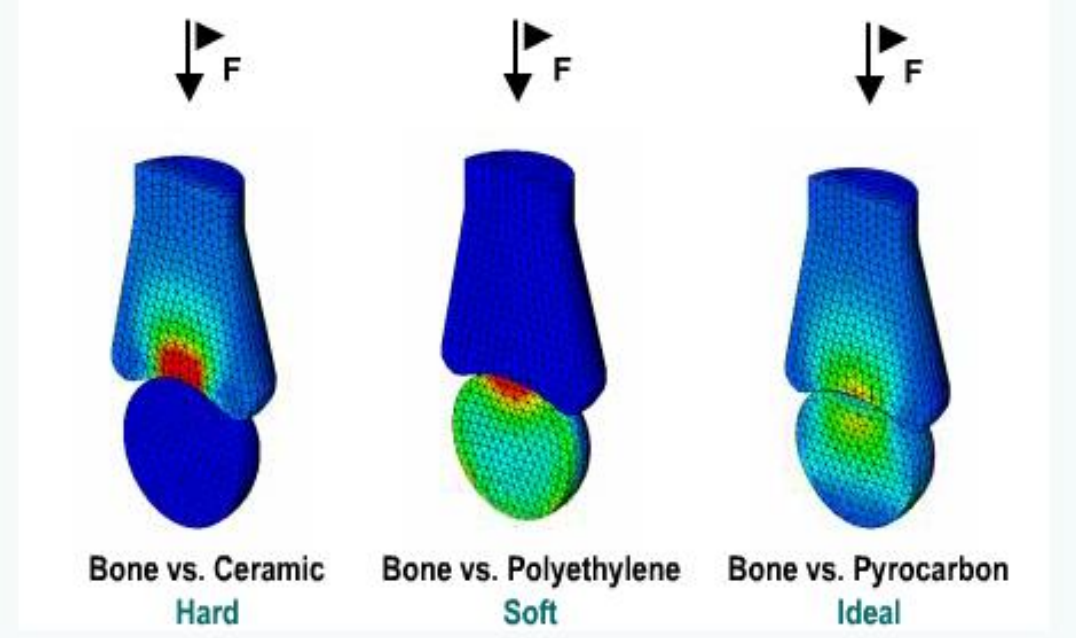
- Only use currently implanted FDA-approved materials

- Materials for articulating surface
  - Silicone
  - Titanium alloy with ceramic
  - Cobalt-Chrome with UHMWPE

Material for Bone Interface

- Stress shielding hinders osteointegration

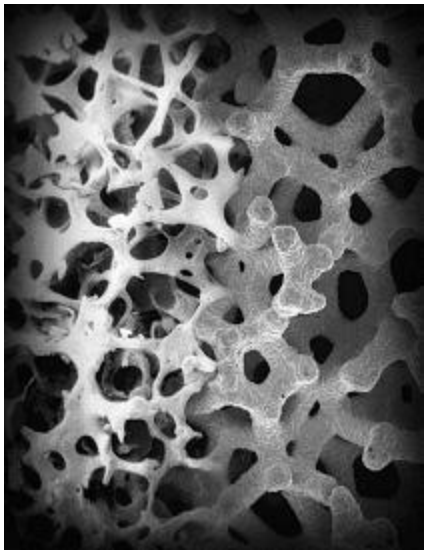
- Mismatch of elastic modulus



Material for Bone Interface

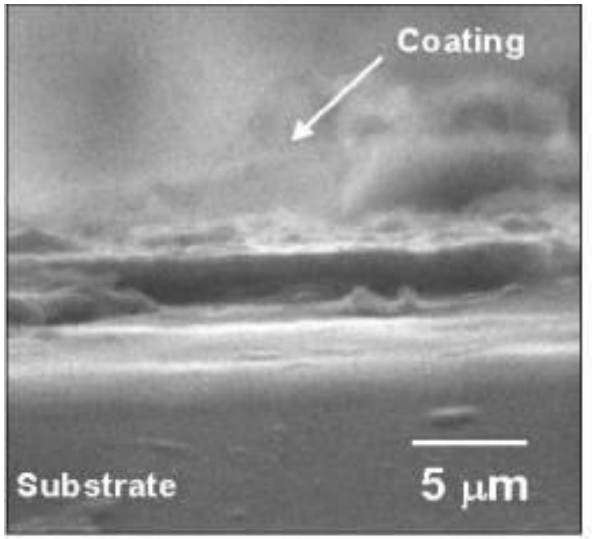
- Pyrocarbon
  - Graphite substrate
  - Similar properties to bone

- Porous Tantalum
  - “Trabecular Metal"
  - Similar properties to bone



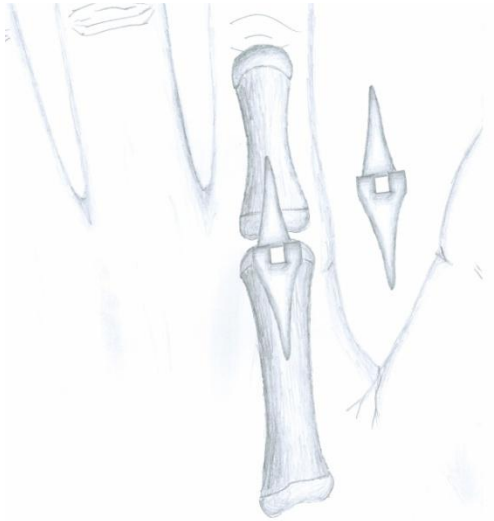
Hydroxyapatite coating

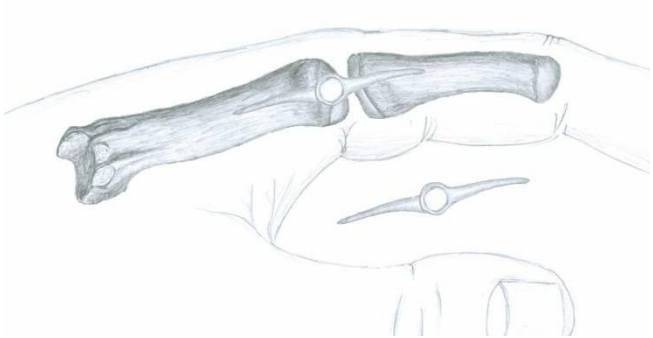
- Crystalline coating
- Proven to promote osteintegration
- Bone is 66% HA
- Only integration mechanism for pyrocarbon



Rigid Hinge

- Advantage
  - Simplicity
- Limitation
  - Does not allow abduction or adduction

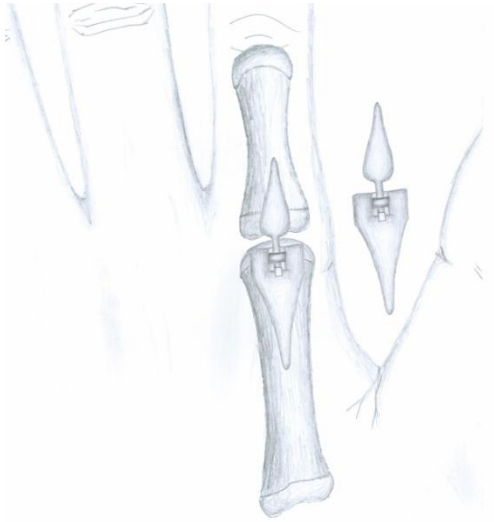


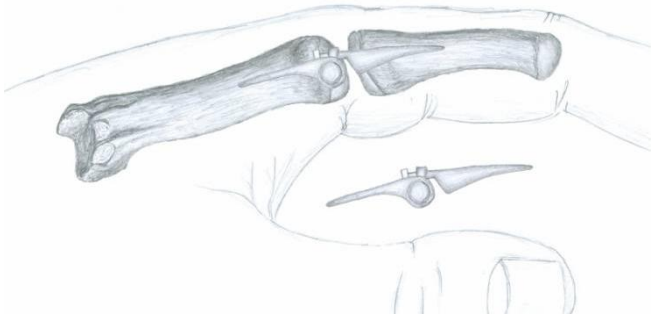


Flexion/ Extension	Abduction/ Adduction	Ease of Implantation	Severity of Failure	Manufacturability	Total
35/35	15/20	10/20	15/20	5/5	80/100

Sloppy Hinge

- Advantage
  - Ideal restriction of flexion/extension
- Limitation
  - Difficult to manufacture

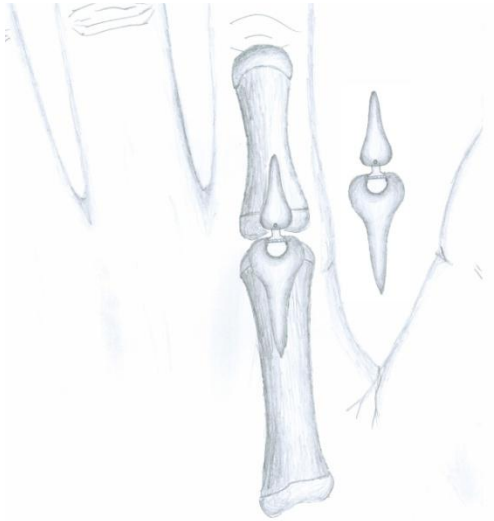


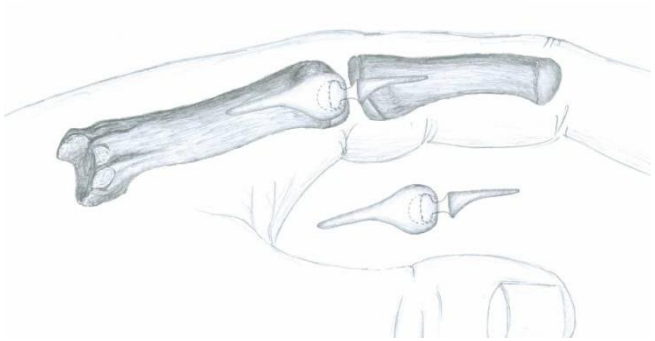


Flexion/ Extension	Abduction/ Adduction	Ease of Implantation	Severity of Failure	Manufacturability	Total
35/35	15/20	10/20	12/20	2/5	74/100

Ball and Socket

- Advantage
  - Ideal restriction of range of motion
- Limitation
  - Difficult to manufacture

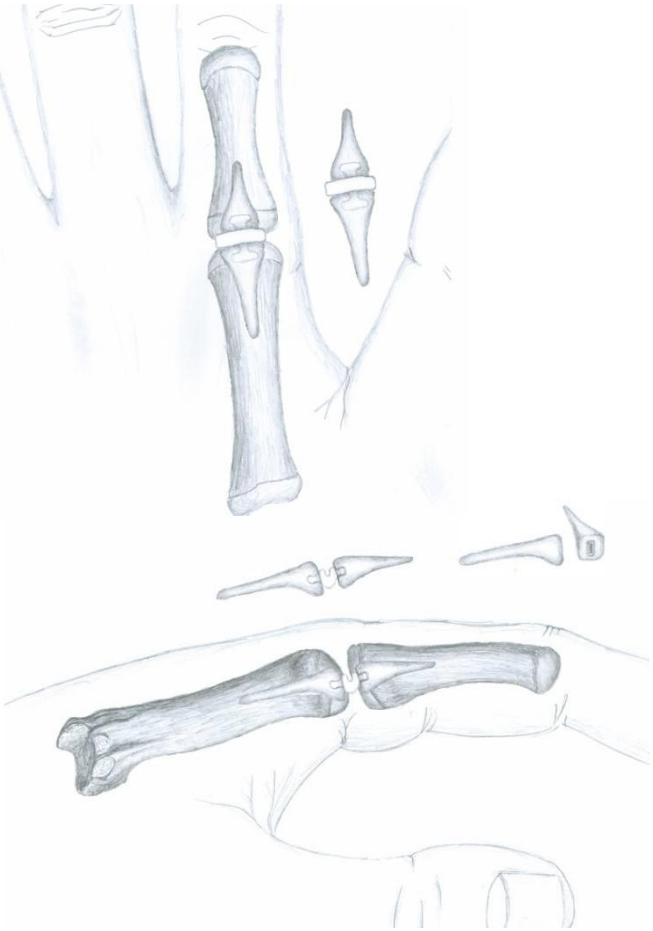




Flexion/ Extension	Abduction/ Adduction	Ease of Implantation	Severity of Failure	Manufacturability	Total
35/35	20/20	15/20	15/20	1/5	86/100

Silicone Hybrid

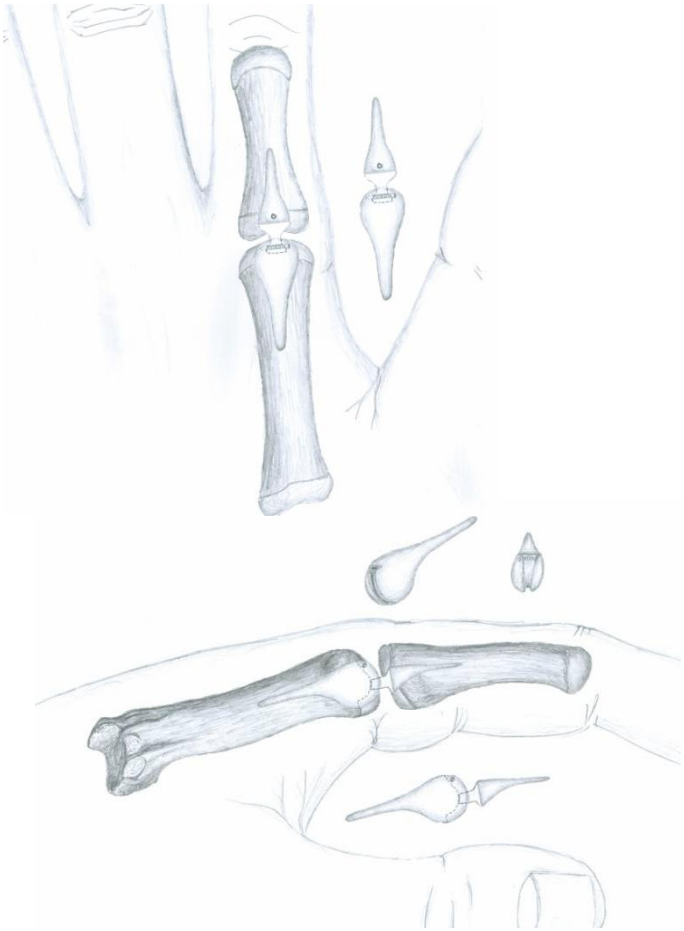
- Advantage
  - Elastic connection between stems absorbs loads
- Limitation
  - Decreased restriction of range of motion



Flexion/ Extension	Abduction/ Adduction	Ease of Implantation	Severity of Failure	Manufacturability	Total
30/35	15/20	10/20	18/20	5/5	78/100

Locking Groove

- Advantage
  - Ideal restriction of range of motion
- Limitation
  - Stress concentrations weaken the implant



Flexion/ Extension	Abduction/ Adduction	Ease of Implantation	Severity of Failure	Manufacturability	Total
35/35	20/20	15/20	15/20	3/5	88/100

Design Matrix

Criterion	Weight	Rigid Hinge	Sloppy Hinge	Ball and Socket	Silicone Hybrid	Locking Groove
ROM: Flexion/ Extension	35	35	35	35	30	35
ROM: Abduction/ Adduction	20	15	15	20	15	20
Ease of Implantation	20	10	10	15	10	15
Consequence of Failure	20	15	12	15	18	15
Manufacturability	5	5	2	1	5	3
Total	**100**	**80**	**74**	**86**	**78**	**88**

Future Work

- Model design in SolidWorks
- Test range of motion
- Perform finite element analysis using various materials
- Fabricate final design

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  - Sarah Duenwald
  - Ben Fjellanger
  - Holly Liske
- Professor Ray Vanderby

Questions?

References

For pictures (in order of appearance)

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- Pyrocarbon http://www.pyrocarbon.com
- Biomet Regenerex http://www.biometitaly.it/userfiles/image/Technologies/Regenerex.jpg
- Hydroxyapatite www.geocities.com/klyphysics/kvpy.html